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No. 736,288



June 14, 1966 ISSUED

166-16

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# CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

APPLICATION No. 897, 460

FILED

PRIORITY DATE

No. OF CLAIMS

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#### LINER EXPANDER

This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

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Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 35 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 23 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 45, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

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A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For exemple, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such 10 as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft 16.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 rounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein  $P_c$  is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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#### I CLAIM:

- 1. A device for expanding a metallic liner inside a conduit which device comprises a shaft element, an expanding die member attached to said shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against said liner by a substantially constant force.
  - 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable cutwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
  - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
  2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a sleeve-like element connected to said movable bearing plate member and slidably positioned on said shaft and a member connected to said shaft to limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.
  - 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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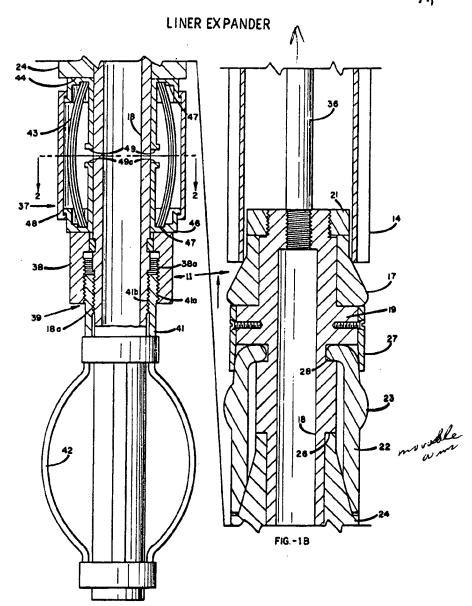
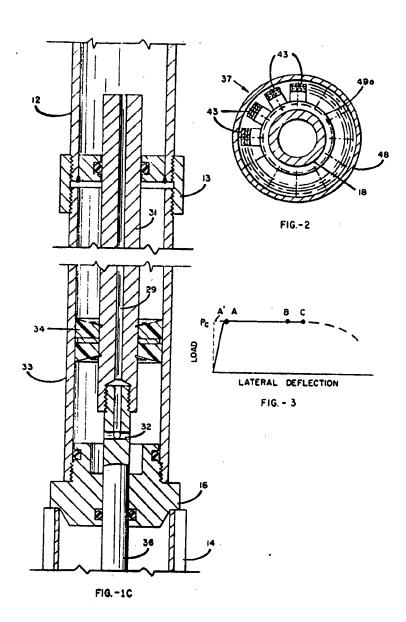


FIG.-1A



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Page 1 of 1



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#### I CLAIM

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1. A dorice for expending a metallic liner invite a condut which device comprises a minit element, on expending the number obtained to said shall closests, which die member comprising a moveble liner-forming member pacitioned on said shall and being radially moveble in respect thereof to contact said liner, as expender momber alightly positioned on said shall between said shall and suid die number to move said liner-forming member from said shall, and a constant force spiring number positioned on said shall to contact said expenses surface and to maintain said expenses suspenses member against main liner-forming member, whereby said liner-forming member is unjob dynamic said liner by a substintially constant force.

2. In a device for installing an expended astallic liner in a combait wherein an expending die is moved through a liner positional in said sombart to expend said liner: a cylistrical start alment, an expending die seeder attached to said shart; said die seeder comprising a plusality of any support disposed around said shart and being phystalla materilly therefore to obstact said liner, a come member allically positioned on said shart between said shart and such assets to very said are members collectly five said shaft, and a commant force spring number positioned on said start to consect stid come member and to saintain said come member in contact with said are members, whereby said age tembers are urged outwardly by a substantially constant force.

j. The device of Claim 2 wherein and constant force spring newtor comprises a plantity of columns disposed account said shaft, a first boaring plate member and a second bearing plate member, each of said bearing plate members contacting opposite cole of said columns, at least one of said bearing plate members being movehly justiceed on said whaft and being in contacts with said come member, stop means commerced to said start to limit the extant traval of said moveble bearing plate number along said shaft, and compression memors for unintaining a lateral defication in said columns.

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- 5. The device of Claim 3 wherein anid shop means comprises a slaves-like element connected to said worship tearing plate member and crishly positioned on said short and a sunface consecuted to said shaft to limit to be bringly of said also well a slaves-like element.
- 6. The device of thate 3 whereis soil columns have a meaning increas-section, the width being greater man the thickness, and having the mider face mount to the dismotor of said shaft.
- 7. A device for installing at expended ustallis liner in a combuit which comprises a sylimitrical shart almostly on accounting the measure measured on said shall, said the senter comprising a plantity of are southern disposed nethroubially around the outside of said shaft and budge plantable cutmaily therefrom to content the liner; a scalent expending master slidebly positioned on said short between said minfs and said are employed to true said re cetterely from said shart; a plantity of electer columns, each bewing a long reutingular areas-sertion and disposed sireumbrandfally shout said chaft; an upper bearing plate member and a lover tearing plate scatter, such slightly positioned on said shaft and contacting opposite onto of said el limiting alseros utrached to each of sold bearing plate numbers and alidably positioned an acid statts a shoulder number on said shafts a differential sower element commercing will shoulder and said stack to apply a lankling load to said enimum; said thoulear being consequate with the limiting means numeried to easil leaver bearing plate nester, whereby the arial traval of maid bearing plate members in limited; said column weekers branchitting their bunkling look to said arm nembers to urgs said and graders substantily with a substantially communication.

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In acceptance with the present invention there is provided a constrat force spring device which comprises a body member, an elongated animal element adjacents said body number, bearing plate numbers contacting the two spin of said column at least one of said bearing plate numbers being longituationally movelys in respect of the other and stop memor as said body missbur to limit the deflection of said solume element to provide parametrized defirmating of said solumn element open the application of a sompressive load thereto. In our exceptance of the invention, the foregoing essential force spring device is employed in a tool for segmenting a smallic liner inside a number, said complete force spring device being positioned on each tool, to ways as expending the senter against the liner being invisited in the combust by a substantially constant force.

My invention will be better understood by returness to the following description and the accompanying drawings wherein:

Figure 14, 18 and 16, taken together, convittute a parkint sevtional view of a preferred embediment of a liner expending tool according to the present invention; and

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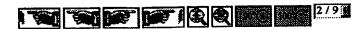
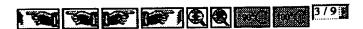




Figure 2 to a sectional view of the apparatus of Figure 1A taken at

Figure ) is a typical plot of applied lock versus deflection for the constant force spring device of the Lavestion.

Referring to the drawings, Figure 14 is the bottom portion of a liner expending tool for one in installing a metallic liner in a well, while Figure 15 tilestrates the middle section of such a tool and Figure 30 represeats the upper sertion of the tool. The expending tool 11 is attembed to stantant will tubing 15 by ampling 15 and, topically, may be lowered from the surface through a well essing (not shown) to a point in the owing at which it is sesired to install a metallic liner. Before inserting the book into the well, an alongsted vartically corregated timer 10 fabricated from mild stool, or ether raiteble salleable material, is placed on the teo). The corrugated liner is occured in position by esement at its upper end with a cylindrical shoulder number 16 and, at the lower and by contact with a first-stage expansiing die 17 in the form of a troncared circular core which serves as a firstmeding 41s in the server bereinsfter described. The expanding die in firedly obtained to a controlly located, elementat cylindrical hollow shaft ld which forms a portion of the body of the tool. As shown, the expending 610 17 is hald in place between a lover shoulder 19 and collar 21 threaded outo the short. . A plumplity of moreple arms 89, preferably provided with outserdly enterged portions 85 mear the top, are disposed in the form of a cylinder ed shaft 18. You enlarged purbloss of the arms 23 wood being moved outvarily equiest the liner to perform the final step of expending the extragal into a substantially systemical shaps. The are seafers HE are postally d to the sheft so me to be movemble outcomfuly from the sheft by a toperad expending number 26 although positioned on the sheft to serve as a second-stage her. The seriese of the master th, as shown, wover specially along the shart to engage with the arms and more them outwardly. Advantageously, the 30 inside surfaces of the area 22 and the outside earlant of expending as form sering sentions, typically categoral is shape. The expension of the most ers is controlled by the position of the master 24 raich moves upwardly





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In operation, the liner setting tool is assembled at the surface, so ribed shows, and a glass cloth saturated with a resumme material may be erapped around the corrugated tota to form the liner. The assembly is lovered the well at the location of which the liner is to be set. A liquid, such so oil, is then pusped under pressure down the salt inking and flows through the restaurest 29 provided is polished not 51, through ports 52 and into epitader 35 completed to the upper and of the shoulder 16. Upon the application of finid pressure to the uplinder, the piston 34 secured to polished red 31 moves operally is splinder 33. As shows, rot 36 cornects polished rot 31 and shart 18 apon which is mounted the first-stage expending die 17. When the piston % artly through the sylindar 33 the expanding die 17 well the secondstage die 22 ere draws upwerdly into the corrupted liner 18 and "iron out" the corregations is the liner, so that the expected liner may correct the famile well of the ceaing in which it is being installed. Positioned on the shaft below the expending member 28 is a comment torce spring member 37 which is employed to mrgs the expending number against the expending some 22 with a substantially sensiant force. The force exacted equinet the emb senders being substantially poststant, the force transmitted through the arm masters to the d to the certing will be substantially constant as that either sticking of the tool in the casing or repture of the caring is precluded. Or course, the chron provided by the spring mester is preselected so that the frictional





forces between the tool and the liner and the pressure exerted against the oneing are maintained at predatared and safe levels. The commission forces spring number exerces that the contact pressure between the liner forming purtion 25 of the erms 22 is great enough to provide the desired deformation of the con-

The equators force spring seasor 77 is alidebly nounted on the shart 18 ced hold between the experding alongst 29 and a sylinarical lower choulder member 35 forcing a portion of a distancetial screw alonest 39 which transmits has looking on spring number 27 to chart number 18. The distancetial coner alongst season occupies about number 18 on the outside of which are one main threads like, the lower shoulder number 18 provided with twente threads 38, and thinkle number 1, provided with threads on the shart and the shoulder. The two seets of threads are number, such as aquars, solidist equars, or force threads, to withstand vary high loads and differ in pitch so that shoulder 38 is sound appearing on the shart 18 when the shart is revolved relative to thinkle 1. The choulder 36 is necessar to the shart 18 by splings 45 so that it can alide longitudinally, but it is not tree to rotate on the shaft. Fixedly arisohed to the lower and of the thinkle is a friction souther, such as box thrings 18, a hydraulically estuated friction pad, or other ruch device for friedinality tousing with respect to the shart. Preferably, the direction of the choulder rotation with respect to the shart. Preferably, the direction of the choulder rotation with respect to the shart. Preferably, the direction of the choulder rotation with respect to the shart and the shart threads 18a, e.g. righthead threads. So, with the pitch, or land, or threads 18a is slightly greater than these of threads 28a, with the pitch rotate thinkle seasons shoulder nember 35 to advance upwerd alightly and a compression load is convited upwardly on apring element 37 to come butting. For example, one retief according threads on a chart approximately 1.7-inch outside dissector and five and threads threads on a chart approximately 1.7-inch outside dissector and five and threads.



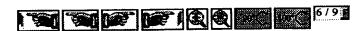


Denotical force spring element 37 comprises unlies element \$3, elementageously consisting of a plurality of alongsted column disposed around shorts.

18. Upper bearing plate samber bk to in contact with the apper ends of the column sed is elimbily positioned on shall if to transact the force of the agring longitudinally against the bottom end of expendin sustant \$6. Lower bearing plate number \$6 contacts the lower seas of the columns and is soved quently along the small by lengthesiani movement of losser smaller \$8 on a result of revelving differential server element \$9. Grooves \$7 are provided in sant of the bearing plates, to form an upper case and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to confure with the shape of the rolumn such it desired. A cover \$8 may be employed to anclade forwige matter from the spring mechanism such to protect

A means for limiting the deflection of the columns to required. Although the column element functions in a backled condition, application of sympactive sumpressive load thereto would sense total failure or repture of the columns. Therefore, a pair of stops by mad its are provided for this purpose. As shown, the stope are rigidly connected to the bearing plates, and, in effort comprise upper and lawar limiting slacres positioned on the shaft to slide longitudinally thereon. The ends of the stope may nowe toward, or easy from, each other so the look in the spring maker wortes. Lover slaves by is prevented from moving down by hower shoulder 56 someouted to the short 18. my, the spacing between the code in much as to limit the longitudinal red of the besting plate members at they move together to prevent perm wiles of the column almost by. Warroom alternative manns for preventing damage to the column element may also be employed. For example, plas or rings someted on the obest may serve as stops, or the cover 48 provides with suitable commentations may be suplicised for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column clement h) may be arranged around the coart 18, which as shown here forces a portion of the body of the spring device, with ends of the columns fitted in the reces by. The solumns may be

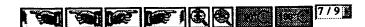


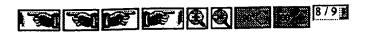


rators used between them to meiatods the desired specing. The ranker of solution myloged will depend upon column characteristics and the amincrials of construction. For example, the standarders ratio of the column may be varied widnly, sent the column make say be round, flat, fixed or hinged. The preservation is a thin, e) under column with tounded ends, free to move within the rances shaped to the correction of the column code. Materials which may be estimated to the acceptance of the column code. Materials which may be estimated to the acceptance of the column code. Materials which may be estimated to the acceptance of the column code. Materials which may be estimated to the acceptance at the column code. Materials which may be estimated to the acceptance of the column and locally simple, such as passagator bronco, benyllium support, the high model alloys and other miniture materials providing actificatory mechanism properties. Typically, the individual columns are of long rectangular cross-cention, with the midth being greater than the likichness, and accepted as that the wider face of the unjumns is accepted to the dimentar of the shaft. Thus, with surficient congruencing loading, the columns backle, and tend short the saint lawting the loast someon of inartia, e.g., outwardly may from the shaft 18.

For example, a group of column 0.167-inch thick by 0.435-inch wife by 10.626-inches long, with the ends youwish, were febrioated from \$.1.8-I 4540 steel, quenched and draws at 575°F. Buth column was found to require a 20 critical compression loading of 1450 pounds in order to bunkle the address. . After bunkling, the columns were found to have a very flat spring characteristio, as shown in Figure 3, therein Po is the critical backling look and point exts the load and deflection at which the stress is the extreme fibers of the solumn exceed the yield point of the untertal. Theoretically, the shape ring characteristic curve is described by enews CA'ABC. Actually, Unis curve is described by 0430 due to friction in the system. Potenta A and B represent typical scring limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large of flexing cycles are not soldcivated, a working stress just below the 30 yield gaint may be used, while with a great number of flexures, the working see say be held to less that the endurence limit of the saterial of sometree tion. In the above-neuritonel teats, the lateral staffaction was limited to

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approximately one just, at which the longitudinal deflortion was approximately 0.825 inches. From more deflection to the assument effection, the \$50-pound loading was froud to be substantially constant.

In emother test a spring device was built, as shows, employing 90 columns, each having a critical buckling load of 1850 posses. The internal declaration was limited between 0 and about 0.00 inches by empropriately positioning the stops. Such compressional limiting, the spring whemset broklet at substantially 25,000 posses and from a longitudinal deflection of 0.00 inshes (buckling) to about 0.15 inches the load reservated substantially at 25,000

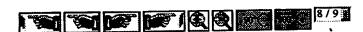
Of caures, in doriging a spring element as above it in advantagements of driving the greatest possible value of longitudinel defluctions for specified values of letteral deflection and critical bushing load, while unintending the stress level to the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 18 and 2, with multiple flat analysis and analysis of seath columns.

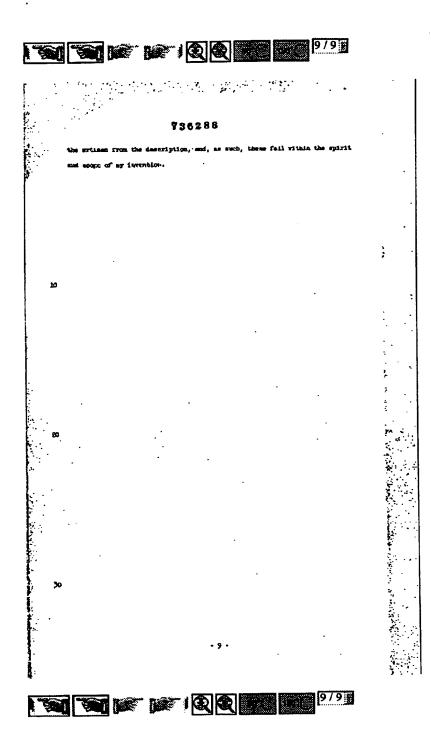
Do the operation of the shows expending tool for setting a liner in well sucked. The made-up tool is lowered into the well as nestigand above, with the area 22 in the retracted position. Then the tool is at the desired level, the well tabing is revolved. The friction matter by capages with the wall of the searing and prevents thinkle 4) true revolving. With several revolutions of the tabing, lower shoulder 35 is nowed momently by differential server 39 to bushle opening almost 37 which has a predefectional critical buckling lead. This lead is transmitted agreedly against the lower ond of expender 26, and the tapered surface is capaged with the tapered surface on the lastes of the eyes 25 to urgs the base cuteurity with a substantially constant force proportional to the critical buckling lead of the spring element. Definencemently, the expending tool is passed through the liner to expend it to the caping in the senser described by stabelone.

the foregring description of a preferred embediagnst of sy invoktion has been given for the purpose of examplification. It will be understood that various medifications in the details of construction will become apparent to

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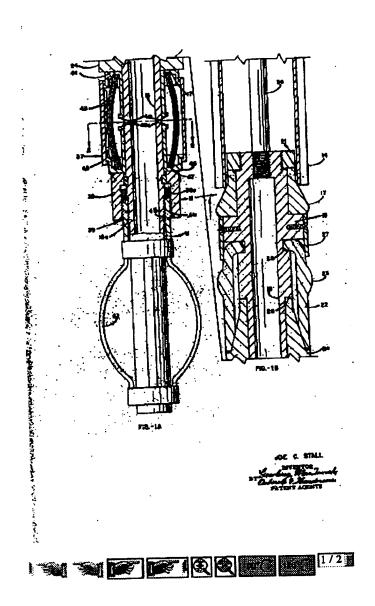
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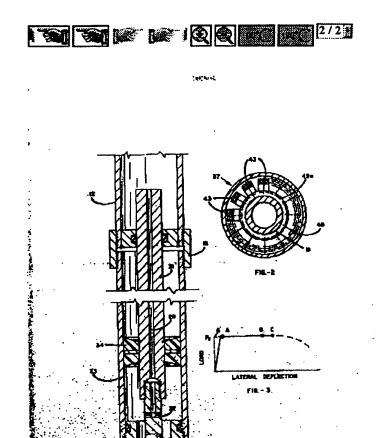




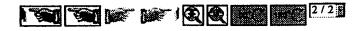


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